# WAS MARTIAN MANTLE WET? A POSSIBLE CONSEQUENCE OF RAPID CORE FORMATION;

Kiyoshi Kuramoto and Takafumi Matsui, Department of Earth and Planetary Physics, University of Tokyo, Bunkyo-ku, Tokyo 113, Japan.

Degassing of $H_2O$ in the planetary interior possibly plays an important role in the evolution of surface environment as well as geologic activity on the terrestrial planets. Mars may be such a planet that well preserves the materials and the geologic features directly related to early evolution of $H_2O$. In this study, we investigate $H_2O$ content in the interior of proto-Mars during accretion and also core formation.

Geodetic data shows that Mars has a dense core [1]. The existence of iron-rich core on Mars may be also supported by the depletion of siderophile elements in SNC meteorites assuming that these samples came from Mars [2]. Isotope systematics of these meteorites indicate that the core formation occurred very early, probably concurrently with Mars formation [3]. Considering the kinetics of metal segregation from silicate, the melting of silicate is likely to precede the core formation [4]. Once the core formation occurs, substantial amount of gravitational energy is released and thus the planetary interior is heated. This energy may be large enough to keep the silicate material in partially molten state along with the accretional heating. Under such circumstances, the silicate melt probably migrates to the surface. Early crustal formation, therefore, is also likely to be associated with the core formation.

For Mars, the main heat source for the planetary interior is probably accretional heating. Short-lived radio-isotope such as $^{26}Al$ may not be important as a heat source because the accretion time of the planets probably much longer than the decay time constant of such isotope. An important feature of the accretional heating is that a growing planet is heated stronger with its growth due to the increase in impact velocity of planetesimals. Then the question is whether or not accretional energy of Mars is large enough to result in surface magma ocean. The critical mass of a growing planet at which the melting of silicate and the core formation begin to occur is uncertain mainly because of difficulty in estimating the efficiency of heat deposition due to planetesimal impact [5]. However, the critical size is estimated to be $\sim 0.5\times$ (present Mars mass), assuming that the impact velocity is equal to the escape velocity of a growing planet, 20% of the impact energy is deposited in subsurface layer, and the core formation occurs when the temperature of subsurface layer exceeds 1500K. This estimate is of course crude but strongly suggests a rapid core formation on Mars. This also implies that the substantial size of undifferentiated core is formed in a growing Mars. Such an undifferentiated core probably contains volatiles like $H_2O$. This is because, although high velocity impact causes the degassing of volatiles such as $H_2O$ contained in accreting materials, Mars is not large enough to experience complete degassing of $H_2O$ during accretion as far as the impact velocity is equal to the escape velocity from the planet [6]. Even if average impact velocity is much higher than the escape velocity due to the perturbation by other planets such as Jupiter, it is unlikely that all the population of planetesimals has the impact velocity high enough to cause the complete degassing. In addition, as inferred from SNC meteorites, the original materials forming Mars is probably volatile rich compared to that for the Earth [7]. Therefore, concurrently with the initiation of the "metallic core" formation, the undifferentiated core may be destroyed and the volatiles may be supplied into the surrounding

WAS MARTIAN MANTLE WET?    Kuramoto K. and Matsui T.

proto-mantle.

$H_2O$ buried in the interior may be removed from silicate due to the reaction between metallic iron and $H_2O$ under high pressure which forms FeO and $FeH_x$ [8]. $FeH_x$ may enter into the core. This reaction might make proto-martian mantle dry. The removal of $H_2O$ from silicate by this mechanism, however, is possibly inefficient when the core formation occurs under the presence of silicate melt. This is because substantial amount of $H_2O$ dissolves into silicate melt. We made a preliminary estimate $H_2O$ partition between silicate melt and metallic iron. The result shows that $H_2O$ is likely to be partitioned into silicate melt more than to metallic iron (Fig.1). Thus, a proto-martian mantle is possibly wet after the core formation.

Possible existence of $H_2O$ in the proto-martian mantle may have a profound influence on the formation of proto-crust and surface hydrosphere on Mars. Silicate melt contained $H_2O$ tends to be silica rich [9] and thus the early crust might have such composition although, at present, the composition of the proto-crust on Mars is poorly known. Because recycling of crust into mantle is probably inactive on Mars, extensive degassing associated with early crustal formation may result in dry martian mantle as inferred from the $H_2O$ abundance in SNC meteorites [10]. $H_2O$ extensively degassed from wet proto-mantle may be a prime source of surface $H_2O$ suggested from geologic flow features on early Mars.

References: [1] B. Bills, 1990. *J. Geophys. Res.* **95**: 14,131–14,136; [2] A. Treiman et.al., 1986. *Geochim. Cosmochim. Acta* **50**: 1,071–1,091; [3] J. Chen and G. Wasserburg, 1986. *Geochim. Cosmochim. Acta* **50**: 955–968; [4] D. Stevenson, 1990. In *Origin of the Earth*, eds. H. Newsom and J. Jones (New York: Oxford Univ. Press), pp. 231–249; [5] G. Davies, 1985. *Icarus* **63**: 45–68 [6] M. Lange and T. Ahrens, 1984. *Earth Plant. Sci. Lett.* **71**: 111–119; [7] G. Dreibus and H. Wänke, 1987. *Icarus* **71**: 225–240; [8] Y. Fukai and T. Suzuki, 1986. *J. Geophys. Res.* **91**: 9,222–9,230; [9] Basaltic Volcanism Study Project, 1981. *Basaltic volcanism on the terrestrial planets*, (New York: Pergamonn Press), [10] M. Carr and H. Wänke, 1992. *Icarus* **98**: 61–71; [11] L. Liu, 1987. *Phys. Earth Planet. Inter.* **49**: 142–167
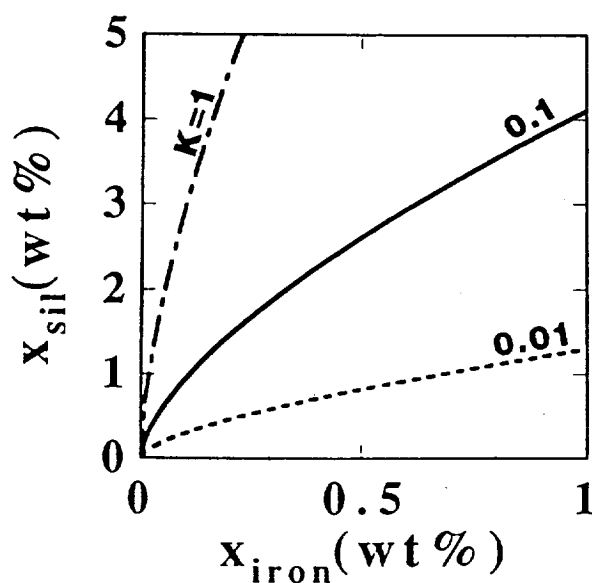


Fig.1. $H_2O$ partition between the silicate melt and liquid metallic iron. On the basis of the data on $H_2O$ solubility in silicate melt [11], $H_2O$ fugacity in the silicate melt is given by $f_{H_2O} = 0.07x_{sil}^2$, where $x_{sil}$ is the concentration of $H_2O$ in silicate melt in wt%. On the basis of estimation of $H_2$ solubility in liquid metallic iron [8], $H_2$ fugacity in liquid iron is approximately given by $f_{H_2} = 12x_{iron}^{1.3}$, where $x_{iron}$ is the concentration of $H_2$ in liquid iron (wt%, but the weight of $H_2$ in liquid iron is converted into that of $H_2O$ for comparison with the silicate melt). $K$ is $f_{H_2O}/f_{H_2}$ which is a function of the temperature and pressure. When Quartz-Iron-Fayalite buffer is considered, $K \sim 10^{-1}$ at temperature 1000~2000K.